Title: Are We on the Same Wavelength?

Link to Outcomes:

- **Problem Solving** Students will solve mathematics and science problems that encourage the use of cooperative learning, brainstorming, teacher demonstration, hands-on activities, and open-ended solutions.

- **Communication** Students will communicate mathematically through diagram and graph construction, as well as brief written descriptions explaining their thought processes.

- **Reasoning** Students will reason mathematically. They will predict, make generalizations based upon patterns they identify, manipulate data in order to make conclusions, and design an experiment to validate their own thinking.

- **Connections** Students will apply mathematical thinking and modeling to solve scientific problems.

- **Measurement** Students will select appropriate units in order to measure the degree of accuracy required in a particular situation. They will develop and manipulate formulas for determining measures to solve problems.

- **Patterns/ Relationships** Students will describe and represent relationships with graphs. They will use patterns to represent and solve problems.

Brief Overview:

This activity generates an elementary mathematical explanation for the scientific concept of waves. Students will experiment with the production of waves and their movement through various media, in order to discover the mathematical relationship among frequency, wavelength and velocity. They will use their findings to suggest a solution to a real-life situation that a working scientist might encounter.

Grade/Level:

Middle school math students (algebra not necessary)

Duration/Length:

This activity should take 3-4 class periods.

Prerequisite Knowledge:

- Students should be able to plot points on a Cartesian graph.
- Students should be able to multiply whole numbers and decimals.
- Students should be able to identify the inverse relationship between multiplication and division.

Objectives:

- Identify the crest and trough of a wave.
- Use the appropriate units of measurement for frequency, wavelength and velocity of a wave.
- Use graph paper to simulate sound wave patterns.
- Compare and contrast wave pattern models.
- Determine the frequency, wavelength and velocity relationship.
- Manipulate a formula.
- Use a simulation to solve a scientific problem.

Materials/Resources/Printed Materials:

The following items are needed for the procedures listed:

Procedure 1

- Per student: "What are waves anyway?" (Worksheet #1)
- Per group: 1 large pan, 1 small piece of wood (or cork), 1 stone, water
- Teacher Demonstration: 1 long piece of rope

Procedure 2

- Per group: 1 set of task cards A,B,C and D, 4 pieces of graph paper, 4 pieces of string (1 meter length), 1 container glue, 1 "Wave Pattern Team Worksheet"(Worksheet #2)
- Per student: "How do we determine the speed of a wave?" (Worksheet #3)

Procedure 3

- Per student: "How do sound waves move through a medium?" (Worksheet #4)

Evaluation

- Per student: "How do geophysicists use sound waves to uncover natural gas and oil?" (Worksheet #5)

Development/Procedures:

Procedure 1:

Distribute Worksheet #1 to the students. The students will complete activities 1 and 2 cooperatively. Then proceed with this demonstration activity:

For this demonstration, the teacher will select one student from the class to assist. The student takes a rope from the teacher and ties it securely to the leg of one of the desks in the front of the room. Making sure that the rope does not touch the floor, the student flips the other end of the rope up, then down, and then back to its first position.

1. What do you observe?

In a wave like the one in this rope, there are two parts: (1) the crest or highest point and (2) the trough or lowest point.

2. Draw a picture of the wave pattern you saw the moving rope produce and label the crest and trough.

The amplitude or energy this wave is transmitting can be determined by looking at the height of the crest or the depth of the trough. Waves with a taller crest (or lower trough) transmit more energy as they travel through a medium than do waves with a shorter crest(or shorter trough).

3. Some ocean waves have a very large amplitude as they move into the shore. What would you expect the energy of these waves to be like, weak or forceful?

4. Sketch two wave patterns, one whose amplitude is greater than the other. Label the wave pattern with the greater amplitude.

Procedure 2:

Arrange the class into groups of 4. Distribute one set of task cards per group. Instruct each student in a group to complete one task card only. Upon completion of the task cards, distribute one "Wave Pattern Team Worksheet" per group (Worksheet #2).

Procedure 3:

Arrange students into pairs to complete "How do we determine the speed of a wave?" (Worksheet #3).

Procedure 4:

Arrange students into groups of 3 or 4. Distribute "How do sound waves move through a medium?" (Worksheet #4). Discuss each question, encouraging students to challenge the results of other groups.

Evaluation:

Today, geophysicists are being hired by various oil companies to lead expeditions in search of new sources of oil and natural gas. One of the devices that a geophysicist would use is a thumper truck. A thumper truck carries a huge vibrator on its underside. As the truck is driven across the desert sand, the vibrator pounds the earth, sending sound waves downward through the rock. Those sound waves are then reflected off the rock layers beneath the sand, back to the earth's surface. Another device, called a seismograph, records the time it takes for the waves to travel through the rock and back again.

Your task is to create two reasonable sets of wave speed data that could actually represent the locations of two different sites, one containing natural gas deposits and the other containing crude oil. Each site is one acre in area. A seismograph usually records 20 wave speed readings per acre. Each reading is recorded in meters per second.

Extension/Follow Up:

These activities are designed for the teacher to use as homework or extra credit assignments.

Activity A

1. Who was Heinrich Hertz and why is he important to what you are now exploring?

Activity B

1. What is a medium?
2. Which medium would transport a wave the fastest: a solid, a liquid, or a gas? Explain your reasoning.

Activity C

1. What is a tsunami?
2. How is a tsunami produced?
3. What is the medium for a tsunami?
4. Predict the amplitude of a tsunami. Explain your reasoning.

Activity D

1. What is an echo?
2. How is an echo produced?
3. What is the medium for an echo?
4. What is the source of energy for an echo?

Activity E

1. What are seismic waves?
2. How are seismic waves produced?
3. What is he medium for seismic waves?
4. What kind of work is done by seismic waves?

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What Are Waves Anyway?

You have heard the word "wave" used in many different ways. For example, you can wave come here to someone. You could have a permanent wave put into your hair or you could make a wave by rowing a boat in the water. For this lesson, however, we will use the scientific definition for a wave. *A wave is a disturbance in a medium that transfers energy progressively from one place to another.* Let's explore what this definition is actually saying. Basically, there are two points to remember: (1) A wave is a disturbance in a medium. (2) A wave moves energy from one point (place) to another. In this definition, the **medium** is some form of matter such as a pool of water, the air in the room, or a piece of rope. A **disturbance** is any part of the medium that has been changed from its normal position.

ACTIVITY ONE

Students should be placed into teams of three or four. As a team, try to remember all of the times you have seen a wave. List all of these examples on a sheet of paper. Now, answer the following questions about your list on another sheet of paper.

(1) In which medium, have you seen each of these waves?
(2) What was responsible for producing each wave?
(3) What kind of work did each of these waves perform?

How Do Waves Travel from Place to Place?

In order for a wave to move energy from place to place, the wave must move through the medium. The medium itself does not move substantially. Let's explore this concept for a moment.

ACTIVITY TWO

Remain within the same teams to do the following activity.

1. Take the pan your team has been given and fill it one-half to three-quarters full of water.
2. Place the piece of wood you have been given into the center of the pan of water with as little splashing as possible.
3. When the water is still, drop the stone into the pan of water and carefully observe what happens.
4. When the stone was dropped into the pan, what was created?
5. How was the wood affected ? Did the piece of wood basically stay in the center of the pan?
6. From our definition of a wave, what acted as the medium in this activity?

Task Card A
1. On a piece of graph paper, construct a Cartesian graph, with the origin (0,0) at the center of the paper.
2. Plot the points (4,4) and (12,-4) to represent the crest and trough of a wave.
3. Using what you have learned about waves, construct the graph of the rest of this wave. Continue your graph to the far right and left sides of the paper.
4. Now use the string to trace the wave. When you have carefully placed it over the graph, glue the string to your graph paper and mark the wave with an A.

Task Card B
1. On a piece of graph paper, construct a Cartesian graph, with the origin (0,0) at the center of the paper.
2. Plot the points (4.5,5) and (7.5,-5) to represent the crest and trough of a wave.
3. Using what you have learned about waves, construct the graph of the rest of this wave. Continue your graph to the far right and left sides of the paper.
4. Now use the string to trace the wave. When you have carefully placed it over the graph, glue the string to your graph paper and mark the wave with a B.

Task Card C
1. On a piece of graph paper, construct a Cartesian graph, with the origin (0,0) at the center of the paper.
2. Plot the points (-8,1) and (-4,-1) to represent the crest and trough of a wave.
3. Using what you have learned about waves, construct the graph of the rest of this wave. Continue your graph to the far right and left sides of the paper.
4. Now use the string to trace the wave. When you have carefully placed it over the graph, glue the string to your graph paper and mark the wave with a C.

Task Card D
1. On a piece of graph paper, construct a Cartesian graph, with the origin (0,0) at the center of the paper.
2. Plot the points (-2,6) and (2,-6) to represent the crest and trough of a wave.
3. Using what you have learned about waves, construct the graph of the rest of this wave. Continue your graph to the far right and left sides of the paper.
4. Now use the string to trace the wave. When you have carefully placed it over the graph, glue the string to your graph paper and mark the wave with a D.

Wave Pattern Team Worksheet

In order to calculate the speed of any wave, you need to know two things: (1) the frequency or the number of waves passing one point per second and (2) the wavelength or the distance between the center point of one wave to the center point of the next wave.

Place the graphs of your team's four waves in the middle of your desks and use them to cooperatively answer the following questions.

1. If the length of your horizontal axis represents a one second interval, which wave pattern (A,B,C,or D) is transmitting the greatest amount of energy? How did you arrive at this answer?

2. Which wave pattern has the greatest frequency? Which has the least frequency? Explain your reasoning.

3. If one centimeter (or one space) on your graph paper equals one meter and one wavelength is the distance from crest to crest, measure the wavelength of each wave pattern. Record your answer below.

How Do We Determine the Speed of a Wave?

Remember, in order to calculate the speed of any wave, you need to know two things: (1) the frequency or the number of waves passing one point per second and (2) the wavelength or the distance between the center point of one wave to the center point of the next wave.

In the same medium, each wave produced travels at the same speed regardless of the amplitude or frequency. Because of this, there is a relationship that exists between frequency, wavelength and speed. This relationship is:

FREQUENCY x WAVELENGTH = VELOCITY (SPEED)

Use this relationship to determine the speed of each wave pattern.

(1) The frequency of a wave pattern is 250 waves/second (hertz) and its wavelength is 3.0 meters/wave. Calculate its velocity in meters/second.

(2) The frequency of a wave pattern is 88 waves/second and its wavelength is 6.5 meters/wave. Calculate its speed in meters/second.

(3) The frequency of a wave pattern is 110 hertz and its wavelength is 8.25 meters/wave. Calculate its velocity in meters/second.

(4) If you know the velocity and frequency of a wave, how would you determine its wavelength?

(5) Suppose a wave has a velocity of 125 meters/second and a frequency of 25 hertz, what is its wavelength?

(6) If you know the velocity and wavelength of a wave, how would you determine its frequency?

(7) Suppose the velocity of a wave is 88 meters/second and its wavelength is 12 meters/wave, what is its frequency?

How Do Sound Waves Move through a Medium?

Remember, a medium is any substance through which a wave is transmitted. Water is the medium for an ocean wave and air is the medium for most sound waves. Basically, all phases of matter can act as a transmitter for a wave. However, it is important to note that the medium can transfer this wave energy with no overall forward motion of itself. The particles of the medium merely vibrate back and forth or move in a small circle.

Sound is a form of energy that causes molecules of a medium to vibrate back and forth. As a result, sound travels through a medium as a longitudinal wave. Scientists have calculated the speed of sound in air as being 340 meters/second, in steel 5200 meters/second, in water 1500 meters/second and in oak 3850 meters/second. Using these calculations, answer the questions below.

(1) Compare the speed of sound through the three phases of matter: solid, liquid and gas.

(2) Experimentalists believe that wave speeds increase the more elastic a substance behaves. If this is correct, which of the four substances mentioned above is the least elastic? the most elastic?

(3) Experimentalists also believe that if two substances are in the same phase, the speed of a wave is decreased as it moves through a denser material. Which substance is the least dense, oak or steel?

(4) If the wavelengths of two sound waves are identical but the mediums are different, what could account for their difference in velocity? Draw a sound wave pattern to illustrate your reasoning.

(5) If the wavelength of each of the above waves was measured to be .25 meters but the speed of wave pattern A is 280 meters/second and the speed of wave pattern B is 520 meters/second, what is the frequency of each wave? Do your calculations support your illustrations?

(6) If a stick was used to strike a steel rod, a drum and a buoy under water simultaneously, predict which sound wave would travel 8,000 meters the fastest. Mathematically explain your prediction.